# Contribution of ALOS, RADARSAT-2 and TerraSAR-X radar data for monitoring agricultural surfaces

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# CONTRIBUTION OF ALOS, RADARSAT-2 AND TERRASAR-X RADAR DATA FOR MONITORING AGRICULTURAL SURFACES

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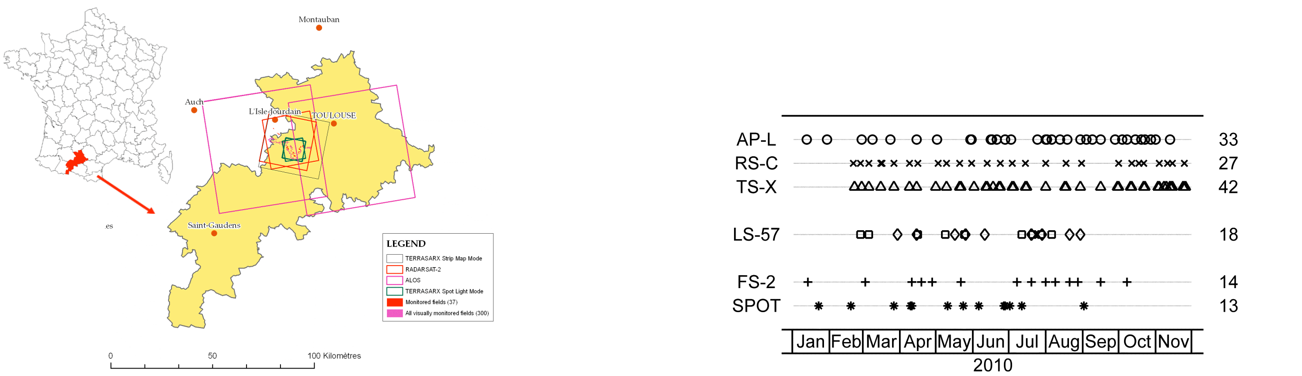
## 1. ABSTRACT

In a changing climate context, it becomes increasingly important to accurately estimate the physical processes involved in the surface-atmosphere interactions in order to predict climate changes and its impact on ecosystems. Increase of human pressure and changes in land use management contribute to alter water and energy budgets as well as carbon sequestration in the soils [1]. Therefore, it is essential 1) to improve our understanding of the different processes governing water, carbon and energy exchanges between the continental biosphere in anthropised areas and the atmosphere, 2) to monitor crop dynamics, soil and crop management and land use change in order to understand the effect of human pressure on biogeochemical cycles. In this study, we used complementary tools for this purpose including field data, remote sensing data and modelling at high spatial resolution to be compatible with the size of the agricultural plots in our area.

The satellite data analysis is performed in 2010 over a studied site located in the south west of France (Figure 1a) where meteorological conditions are steered by a temperate climate [2]. They are compared with ground data measurements acquired synchronously with all satellite acquisitions (Figure 1b).




a) b)

**Figure 1: Presentation of the studied sites superimposed with the swaths of ALOS (AP-L), TERRASARX (TS-X) and RADARSAT2 (RS-C) images (a) and their temporal sampling (b) in 2010. Optical and thermal acquisitions provided by SPOT, FORMOSAT2 and Landsat5-7 satellites are not used in this study.**

At the local scale, three test sites are instrumented with meteorological stations since 2004. During the year 2010, complementary measures are performed over 37 sites for different soil types (texture, depth) and for the main crops encountered in France and Europe (wheat, maize, sunflower, soybean and rapeseed). These additional measurements concern the soil surface roughness and the soil surface moisture (*SSM*) performed by using respectively a 2 m pin profiler and manual Theta probe sensors. Soil roughness statistical parameters (correlation length, type of the autocorrelation function and rms height) are estimated from four profiles performed in parallel and perpendicular to the direction of the tillage. One SSM measurement is performed every 15m along several hundred meters transects depending on the field size. For each transect measurement, the mean SSM and its standard deviation are computed, they are assumed to be representative at the field scale (figure 2).

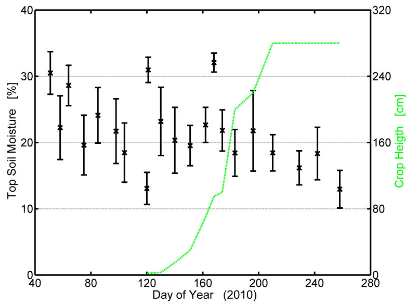



**Figure 2: Example of one of the 37 temporal evolution of *SSM* (mean and standard deviation are plotted). This site is corn cultivated (green curve), and the soil is mainly composed of clay (>50%).**

Wet and dry biomass distribution, vegetation height measurements are also performed during the crop phenological cycles. At regional scale, 350 fields are also monitored to identify crop species, soil management, soil tillage orientation… providing a wide dataset of different soil and vegetation status.

Although this work is included in an assimilation scheme for multispectral data (optical, thermal and microwaves), the analysis of the satellite data is here mainly focused on high spatial resolution (meter) microwave data to complete all the analyses performed with lower resolution sensors from ERS scatterometer or ASAR coarse mode data (over crops or natural vegetation) [3]-[9]. Combined to the high spatial resolution data, the contribution of multi-frequency data (L-, C- and X-Band) is assessed by using quasi-synchronous data provided by ALOS, RADARSAT-2 and TERRASAR-X satellites for monitoring the spatio-temporal variations of the surface properties (soil roughness, soil moisture, and vegetation status) associated to crop management (tillage, irrigation, fertilisation application…). In the following, results only focuses on surface soil moisture and soil roughness estimated from empirical and physicals methods. Soil management (ploughing, tillage, sowing…) and vegetation monitoring purposes are not discussed in this paper. Figure 3 shows an example of color-composed images over the region of interest in April and May 2010 processed by combining X, C and L-band images respectively displayed on red, green and blue colors. All images are acquired in HH polarization.

a) b)

**Figure 3: Color-composed images over the studied area in April (2010-04-14) and May (2010-05-01) processed by combining X, C and L band images respectively displayed on red, green and blue colors.**

The highly contrasted images indicate the great potentialities of multi-frequency radar signal to better estimate surfaces parameters, especially the surface soil moisture. Statistical analyses, not presented here, show that the use of different backscattering coefficient ratio between L-, C- and X-band data $\left(\frac{\sigma_X^0\left(\theta_{view\ incidence\ angle},\theta_{field\ orientation}\right)}{\sigma_L^0\left(\theta_{view\ incidence\ angle},\theta_{field\ orientation}\right)},\frac{\sigma_X^0\left(\theta_{view\ incidence\ angle},\theta_{field\ orientation}\right)}{\sigma_C^0\left(\theta_{view\ incidence\ angle},\theta_{field\ orientation}\right)},...\right)$, and the complementarities of view incidence angle allow improving the monitoring of surface soil moisture and soil roughness. Best estimates are performed by taking into account the most suitable radar configuration depending on vegetation biomass, vegetation height and surface soil roughness. $\left(SSM\left(\%m^3.m^{-3}\right)=f\left(\sigma_L^0,\sigma_C^0,\sigma_X^0,vegetation,soil\,roughness,...\right)\right)$.

The physical inversion of the surface soil moisture is processed by using different models suited for remote sensing purposes (Dubois, Oh and Integral Equation Model). Comparisons of the modelled backscattering coefficients (from IEM and Dubois models) versus observations are presented in figure 4.

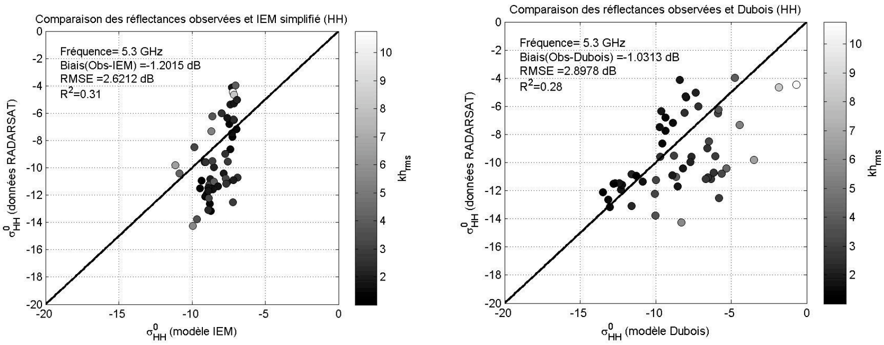



**Figure 4: Comparisons of simulated backscattering coefficients by using the IEM model (a) and Dubois Model (b) versus satellite observations. C-band results are here presented at HH polarization.**

Final results, not shown here, give an overview of models capabilities for backscattering coefficient simulations and summarize their potential for surface soil moisture inversion. Different radar configuration (frequency, view angle…) and soil states (moisture, roughness…) are investigated.

This approach is consistent with previous studies performed in microwave multi-frequency analyses over crops ([10]-[11]) and with the launch of future multi sensors satellites constellations which will combine optical and radar data (Sentinel and Pléiades projects [12], [13]).

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